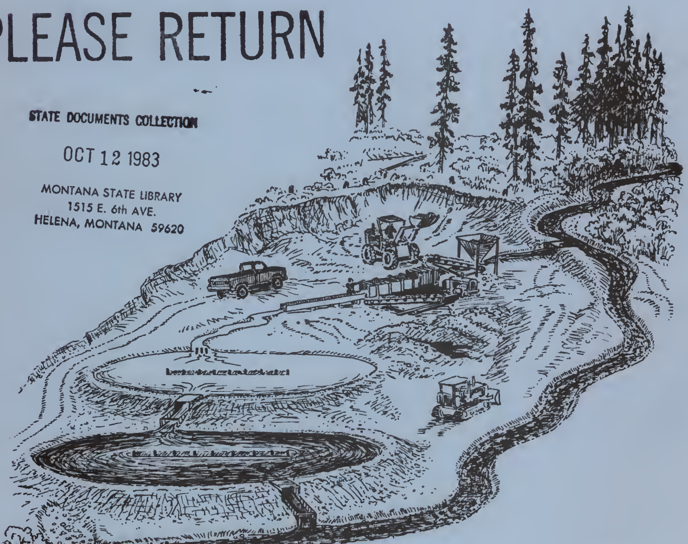
SETTLING POND HANDBOOK



SETTLING POND HANDBOOK

Written by the Alaska Department of Environmental Conservation

funded by a grant from the U.S. Environmental Protection Agency

April 1981

Edited by the Montana Department of Health & Environmental Sciences
Water Quality Bureau
and
the Montana Department of State Lands
Hard Rock Bureau

April 1982

Table of Contents

Page

I. Introduction 1

II. Land and Water Management Agencies 1

III. Settling Pond Design Considerations 3

A. General Comments 3
B. Standards to Meet 4
C. Pond Design

1. Soil Considerations 5
2. Topographic Considerations 6
3. Pond Sizing 7
4. Pond Dimensions 9
5. Baffles 10
6. Construction Material 11
7. Inlet Structures 12
8. Outlet Structures 13
9. Construction and Maintenance Equipment 14

D. Pond Performance

1. Examples of Bad Design Layout 15
2. Examples of Good Design Layout 16

IV. Other Treatment Methods

A. Tailing Filters 17
B. Filter Fabric 17
C. Land Application and Vegetative Filters 19
D. Diversion Ditches and Storm Surges 20

V. Conclusions 22

SETTLING POND HANDBOOK

The purpose of this handbook is to discuss and illustrate mining practices that will reduce the amount of soil particles in wastewater discharges from mining operations. The involvement of land and water management agencies will also be described briefly.

I. INTRODUCTION

The adage "gold is where you find it" indicates that mining occurs where the mineral is formed or collected, not where environmental conditions are favorable. Geology, terrain, climate, geography, hydrology, accessibility and economics all impose constraints on mining practices. Quite often, theoretical designs for mining operations cannot be met by the miner because of these constraints. For this reason, this handbook should be used as a guide. It is hoped that it will be of help in developing innovative methods to reduce the amount of sediment that reaches Montana's creeks and rivers.

The section on permits is general. Specific information about permits may be obtained directly from the concerned agency. Montana's Permit Coordinator can supply general information and assist in applying for permits. Write or call:

Permit Coordinator
Office of the Governor
Capitol Station
Helena, Montana 59620

Phone: 406/449-3111

II. LAND AND WATER MANAGEMENT AGENCIES

1. Montana Department of State Lands

Mining activities must obtain an operating permit from the Department of State Lands. A reclamation and vegetation bond is required, and a reclamation plan must be submitted. Annual reports and fees are required; the department makes annual inspections for compliance with the reclamation plan of the mining operation. Exemptions may be available for small mining operations. Contact the Department of State Lands, Reclamation Division in Helena at 449-4560.

2. Local Conservation District or Board of County Commissioners

Any physical alteration of a natural perennial flowing stream, its bed, or immediate banks requires approval from either the local Conservation District Supervisor or the Board of County Commissioners. This authorization is given under the Natural Streambed and Land Preservation Act, commonly known as the 310 permit.

3. Montana Department of Health and Environmental Sciences

All industrial processors (including miners) who discharge waste water to State waters (any body of water, irrigation system or drainage system, either surface or underground, except irrigation systems where the waters are entirely used up) require a discharge permit.

If you have any questions regarding discharge permits or water pollution, contact the Montana Department of Health and Environmental Sciences, Water Quality Bureau in Helena at 449-2406 or by writing to:

Montana Department of Health and Environmental Sciences
Water Quality Bureau
A206 Cogswell Building
Helena, Montana 59620

4. Montana Department of Natural Resources and Conservation

A mining activity may be subject to the Montana Water Use Act if it is appropriating surface water or groundwater. Before water can be diverted or impounded for a new use, or change an established use of water in any way, a permit from the Department of Natural Resources and Conservation must be acquired. This includes water removed from a stream for the purposes of dredge mining.

Contact the Water Rights Bureau of the Department of Natural Resources and Conservation in Helena at 449-3634 or by writing to:

Montana Department of Natural Resources
Water Rights Bureau
Capitol Station
Helena, Montana 59620

5. U.S. Forest Service

If a mining activity occurs on or will disturb National Forest Land, please check with the local ranger district of the National Forest. A "Notice of Intent" and possibly a "Plan of Operation" will be required by the Forest Service.

6. Bureau of Land Management

Mining activities on lands administered by the Bureau of Land Management should contact the BLM District Office which administers the lands where the activity occurs. District Offices are located at the following addresses:

P.O. Box 30157
Billings, Montana 59107

P.O. Box B
Malta, Montana 59533

P.O. Box 940
Miles City, Montana 59301

Federal Building
Butte, Montana 59701

III. SETTLING POND DESIGN CONSIDERATIONS

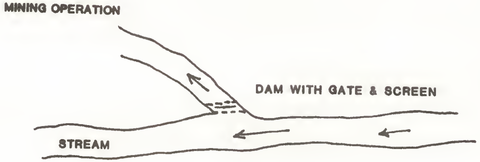
A. General Comments

1. Settling ponds are the most commonly used means of treating wastewater to remove sediment and prevent deposits of unwanted sediment on nearby downstream lands or waters. In many instances, settling ponds also act as a reservoir to conserve scarce water for recycling through the mining process.

2. A minimum of water should be used: the less water used to mine, the less wastewater that needs to be treated. Any device or method that can be used to cut down water use and treatment costs, helps.

Classification of sluice feed material (using grizzlies, trommels, screens, wobblers, vibrating tables, washing plants and conveyors) is helpful in cutting down on the water used.

3. Creeks should be split with wing dams allowing only the water needed for an operation to be diverted (see below). These dams can be closed during storms and flooding.



4. Recirculation of water may be necessary when there is little water available. It will pay the operator to treat recycled water before pumping to prevent wear on pumps and to get a higher duty from the water. (Duty is the muck-carrying capacity of water.) Clean water does a better job in the sluice box because it transports more material than dirty water.

B. Standards to Meet

Ponds should be built in such a manner as to reach the required treatment level. The Montana Department of Health and Environmental Sciences has specific requirements that are included on the discharge permit. This permit is needed for any wastewater discharge into a creek, river, pond, lake or other body of water (see page 2 , part II, #3).

The two most important criteria for sediment control on the present permits are those for settleable solids and turbidity. Settleable solids are the soil particles suspended in the water that will settle under the influence of gravity if the water is calm. This usually does not include clay-size particles. Turbidity is a measure of the amount of light that is scattered and absorbed by any particles in water, rather than passing in straight lines through the water; for example, when visual depth is restricted. The requirement is 5 NTU (nephelometric turbidity units) above natural stream background (the amount of turbidity the stream has before people's activities change it). The measuring point is 500 feet downstream from where the wastewater is discharged.

These standards are part of Montana's Water Quality Standards. They were established to conserve water by protecting, maintaining, and improving the quality and potability of water for public water supplies, wildlife, fish and aquatic life, agriculture, industry, recreation, and other beneficial uses.

C. Pond Design

There are three general rules of thumb for the design of settling pond systems:

1) Pond treatment methods should be kept as simple as possible.

2. Good engineering will result in significantly improved recovery efficiency and improved effluent at minimial cost.

3. As little water as possible should be used.

Factors which should be considered in the design and construction of a pond are described on the following pages.

1. Soil Considerations

There are three basic soil texture sizes: sand, silt and clay. It is rare to find soils that are made up entirely of one texture size. Often soils are made up of a combination of sand, silt and clay and might be called a sandy-silt-loam soil. Should soil particles be encountered in their free state, sand is gritty, silt when dry has a talc-like feel, and clay if wetted is stocky and very pliable and elastic. Sand has the largest soil particle size, clay the smallest. The finer the texture, the longer it takes to settle.

Sand, when dominant, form a coarse-textured or "light" soil that allows water to infiltrate rapidly. Silts and clays make up fine-textured or "heavy" soils. They are often quite cohesive, slow to erode and low in permeability (slow to drain). These soils are frequently the worst polluters, because fine-grained particles settle slowly, travel farther and may be held in colloidal suspension. Also, the clay-sized particles are the most difficult to settle out

of suspension and may require tremendously large basins in order to conform to water quality criteria. Soils that are high in silt and fine sand and low in clay and organic matter are generally the most erodible, but are also easier to settle out.

DIAMETER OF PARTCLE (MM)	TYPE OF SOIL	SETTLING VALUE (MM/SEC)	TIME TO SETTLE ONE FOOT
.06-.4	SAND	3.8-4.2	1.3 MINUTES- 7.3 SECONDS
.003-.05	SILT	.0138-2.9	6.2 HOURS- 1.8 MINUTES
.002 & SMALLER	CLAY	.0062 & SLOWER	13.6 HOURS-YEARS

To determine whether a pond will work, take a soil sample to a laboratory to find out is composition. In the soils lab, soil samples are dried and soil is poured through standard sets of graduated sieve sizes. Settling and handling characteristics can be estimated from the percentage of each particle size in the sample. The jar sample method, described later, may be used for a rough estimate.

2. Topographic Considerations

Topographic considerations may dictate the need for several ponds in a series to obtain sufficient volume for an adequate detention time. The use of multiple ponds has advantages over one large pond for the following reasons:

1) Passing water from one pond to another probably increases detention time.

2) The first pond can act as a pre-treatment pond.

3) Smaller ponds are easier to clean with the equipment that is normally available.

4) It is easier to adjust, remove or rehabilitate smaller ponds.

3. Pond Sizing

There are at least three methods to determine the size a settling pond should be made: using theoretical calculations, using a predetermined detention time, and using approximations based on a sample of the process water. The theoretical method requires a lab to handle sample analysis and involves lengthy calculations, so it will not be discussed here. For field use the detention time method appears to be easiest, although the jar sample method is not too complicated.

Detention Time Method of Sizing: This method of determining pond size involves calculating the area a pond would need to contain the volume of water that will be discharged into that pond during a specific period of time. To do this, you only need to measure the amount of water and convert this volume of storage area needed.

For example: if a small sluice box uses 900 gallons of water per minute and is operated for 10 hours a day:

900 gal/min x 60 min/hr x 10 hr/day = 540,000 gal/day (amount of water discharge)

540,000 gal/day x 0.1337 cubic ft/gal = 72,000 cu ft/day (size of pond needed)

Assuming the pond has minimum depth of 5 feet, the surface area would be:

72,200 cu ft ÷ 5 ft = 14,400 sq ft (about 1/3 acre)

Theoretically, this would be ample to hold the amount of water used in one day.

The initial estimated size makes no provision for reduced capacity due to filling in by sediment. The pond area may be increased by 50% to 100% to allow for lack of ideal configuration and for volume lost by sedimentation. The basic estimate also does not consider the desirability of having maximum surface area; surface area is a major feature of sediment removal. In general, the surface area, the rate of discharge of the pond, and the settling rate of the particles determine the effective performance of the system. The depth of the pond and retention time have less effect on the successful removal of sediment.

Jar Sample Method of Sizing: This method estimates pond size from the settling time for the sample. Pond area is calculated by applying the settling rate to the volume of treatment water expected. An estimate of settling time can be made by mixing the fines with water in a jar and observing the results as the sediment settles. Settling is complete when there is uniformly clear water above a clearing defined layer of settled material. The time taken will approximate settling time required in a pond. The jar should be cylindrical in shape and calibrated so that height can be measured in the water column.

For example, if the settling time in the jar is observed to be 4 hours, and the inflow rate is 30,000 gallons per hour, the pond must contain:

30,000 gal/hr x 4 hr = 120,000 gallons, or:

120,000 gallons x 0.1337 cu ft/gal = 16,000 cu ft.

Assuming the pond will be 4 feet deep, the surface area would be:

16,000 cu ft ÷ 4 ft = 4,000 sq. ft.

It should be noted that the lower practical size of particles that will settle under the influence of gravity is about 0.01 mm. The jar sample method is also a practical test for settling characteristics.

Regardless of the method used, it is helpful to know:

1) The amount of water used per day.

2) The types of soil particles in the working area.

3) The water temperature (cold water carries more muck, but warm water is better for settling).

4) Topographic information (for pond design).

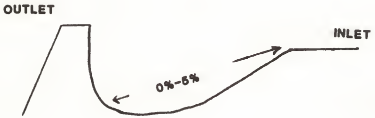
The pond should be allowed to operate to determine if enough sediment is settling out to meet permit requirements. Perhaps lower feeding rates or recirculation can be tried if the system fails to meet the standards. Experience and trial-and-error under site-specific situations remain the best guide to achieving good settling pond design.

4. Pond Dimensions

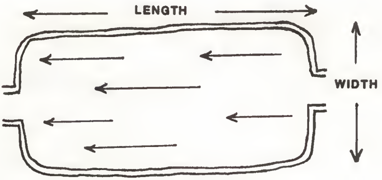
Ponds must be deep enough to prevent hydraulic scouring and short-circuiting, and to minimize bottom load movements. Additional depth should be provided for storage area so the pond does not require frequent cleaning and will have a longer life. When the pond has filled with sediment within 2 feet of the surface it should be cleaned or abandoned. High water can cause scouring and can induce turbulence which will stir up the silt in filled ponds.

Shallow ponds may, however, be more efficient than deep ponds because the water can warm up to allow better settling. Shallow ponds can also be safer: if the lower dike should breach, the threat of flooding would be much less.

The optimum grade for a pond is 0%-5% slope from the inlet to the outlet, as shown below.



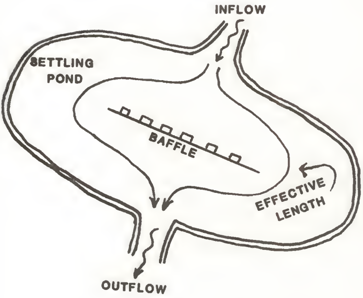
Pond length should be at least two times greater than its width.

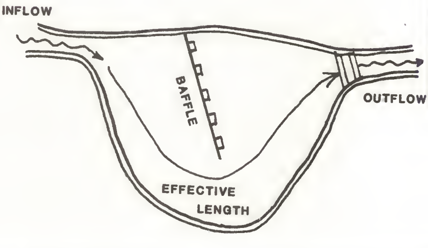


These proportions allow uniform flow rates and increase detention times. If water appears to flow in a sheet pattern, it is good. If the water and sediment load swirl, boil or channelize, the pond is short-circuiting and you will need to alter your design to prevent this. Where ponds cannot be built to allow for 2 x length vs. width, then baffles can be used to increase detention time and prevent short-circuits.

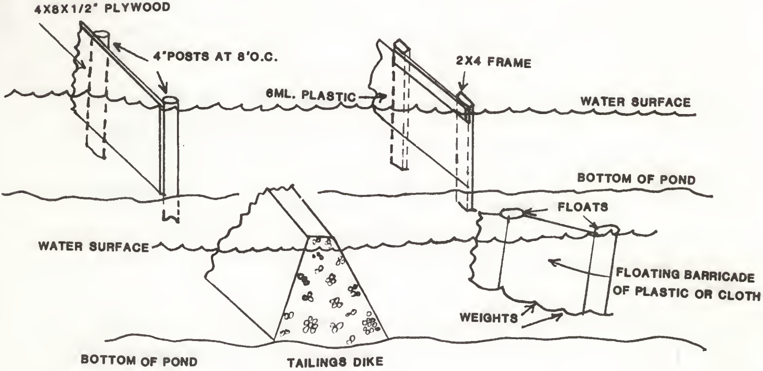
5. Baffles

Very few mining locations allow construction of ideally shaped ponds. The ponds are confined by the topography, so that inlets and outlets are often fairly close together. If this is the case, baffles can be used to prevent direct flow from inlet to outlet (short-circuiting). Properly placed baffles increase the effective length of the pond and, therefore, retention time. The effective length of the length of the shortest flow path between the inlet and outlet. Examples are shown below, with baffles placed to deflect the water and increase the effective lengths of the ponds.



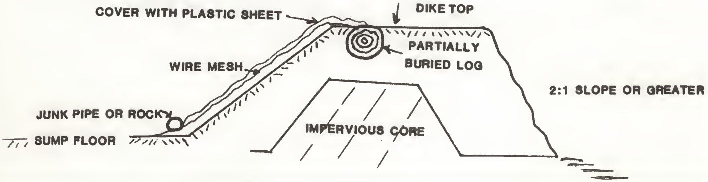


Construction details of baffles are shown here. Baffles can be built of posts driven into the bottom of the pond and facted with plywood or lumber, or heavy plastic sheeting held top and bottom in a wood frame. Dikes of tailings pushed into the pond, or even floating barricades of plastic or cloth, can also be used as baffles (see page 14).



6. Construction Material

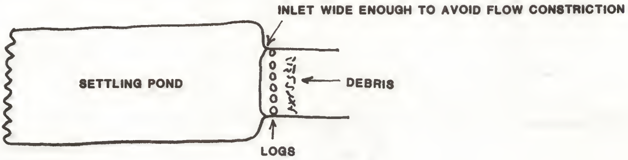
Sand and gravel make poor settling pond containment dikes. (For a discussion of sand and gravel filter dikes, see the section "Tailings Filters." If possible, fines should be mixed with coarse material to provide an impervious core. However, if this is not possible, a visqueen (plastic) liner can be used (see diagram below).



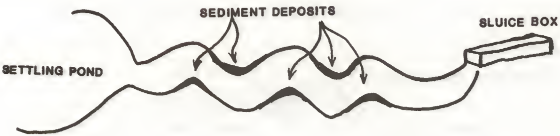
7. Inlet Structures

Both inlet and outlet structures should be made of material that will not erode. Concrete, metal, rock, rock-filled gabions and wood all work. The inlet structure should be wide enough to avoid constriction of the flow at the entrance; this will help reduce water velocity.

Energy dissipaters placed above the pond entrance also help reduce water velocity. This minimizes the potential for short-circuiting. The diagram here shows a log structure upstream of a sediment pond, acting as an energy dissipater.

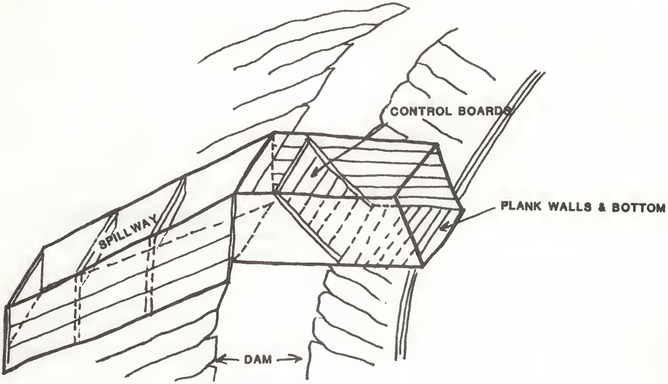


It has been found that settling ponds are more effective if sluiced material is discharged to a meandering raceway that leads to the pond. This allows coarse sand and larger tailings particles to settle out before they reach the settling pond, sometimes up to 50% of the total material processed. The sediment deposits are easy to remove with bulldozer.

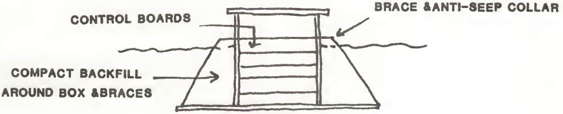


8. Outlet Structures

Outlet structures should be as wide as possible to allow for a sheet type of flow across them. These structures need to be built of durable material. Plywood may be the easiest material to obtain and to work with.

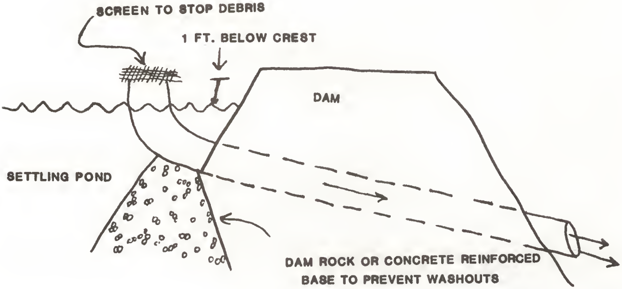


The outlet structure should be designed to handle storm water volumes. One method is to place control boards in the spillway, as shown here. The overflow gate, made of wood or metal, can be reused.



SECTION VIEW

A second means of controlling storm water within the pond is to construct a riser near the outlet. The riser should be attached with a watertight seal and be heavy so it will not float. It can be made of any type of pipe; about 10-18 inches in diameter is the size most often used.



9. Construction and Maintenance Equipment

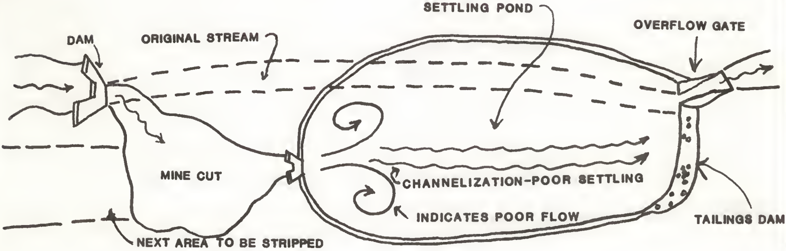
Probably the best single piece of equipment for pond building and maintenance is the dragline. Backhoes also work for small ponds. Note: Extreme caution is required when cleaning ponds using loaders or bulldozers, as it is easy for equipment to get stuck in the accumulated soft muck.

D. Pond Performance

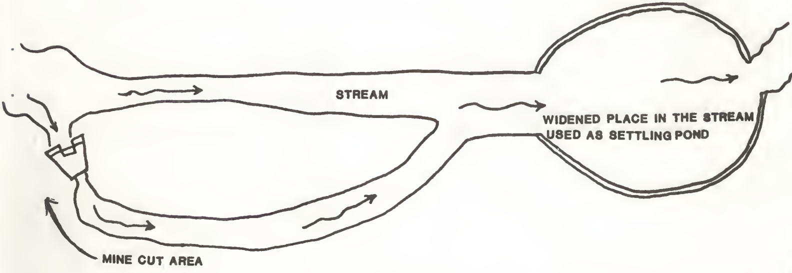
Check your pond occasionally (or at least as often as your permit requires) to see whether you are meeting the required treatment standard. The jar sample method provides an easy, reliable test.

1. Examples of Bad Design Layout

Shown here are two settling ponds with poor layout. The settling pond shown below is created by damming the small stream. Therefore it is subject to washout when the stream flow exceeds the process water volume.

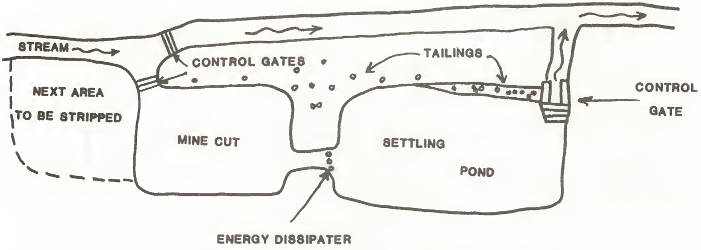


In the layout below, the stream water and the process water are allowed to mix before they reach the settling pond. This not only cuts down the detention time, but also loses untreated water downstream.

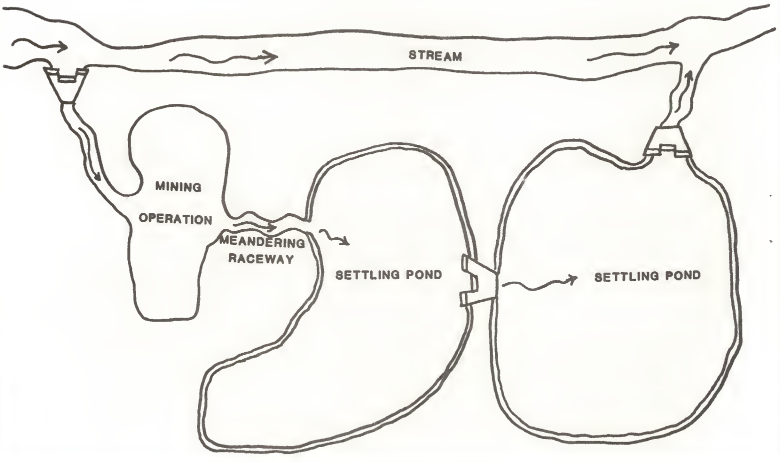


2. Examples of Good Design Layout

Two settling ponds with good layouts are shown here. If circumstances require a setup where flooding can occur, the mine workings and settling pond should be protected from flooding by gates and stream diversion such as shown here.



This drawing shows two ponds that are irregularly shaped. Baffles can be used, or more ponds constructed as mining progresses upstream.



IV. OTHER TREATMENT METHODS

A. Tailings Filter Dams

A filter dam is constructed of material which allows a slow flow of wastewater through it, but traps the sediment. Material such as fine gravel, or coarse sand often found in placer tailings may work well for filter dam construction.

Large mined-out flat or gently sloping areas can be used as a filter system without building dikes, dams or ponds. This requires relatively large areas and in most cases filter dams will help. If carefully constructed, filter dams can be more effective than settling ponds for sediment reduction. Often a series of filter dams can be used, and mine tailings can be disposed of by placing them in a manner that will build a filtration system.

The amount of filtration that can be accomplished by passing sediment-laden water through a layer of tailings is dependent upon the thickness of the layer, the gradation of the tailings, their size, and the physical characteristics of the suspended sediments, as well as the application of the wastewater to be filtered. Design of the system must allow for natural runoff and spring and summer flooding, in addition to wastewater flow. Many dams have failed. Proper design is, therefore, a necessity. Assembling the information on soils is the essential first step in designing a dam for use as an embankment. This will help determine the dam's stability for the various conditions of operation. Provision should be made for breaching the dam at the end of the season to prevent damage to the dam from freezing and accumulation of ice in the storage basin.

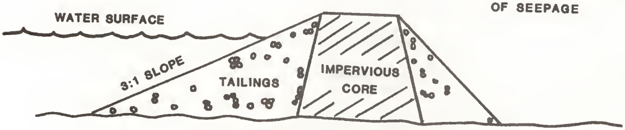
Note: It is always necessary to construct spillways and provide for storm surges and winter damage.

B. Filter Fabric (silt fence)

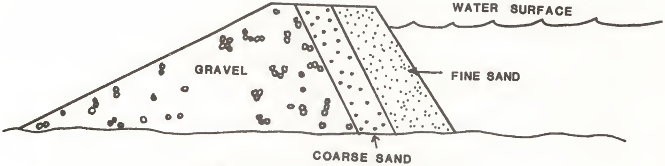
Filter fabric material can be used in the same way as filter dams. This fabric allows water to flow through its pores and holds back the sediment. Filter fabric is also used as silt fences, to control erosion by diverting and slowing runoff from steep slopes or other unstable soils.

TAILINGS DAM USED AS A FILTER

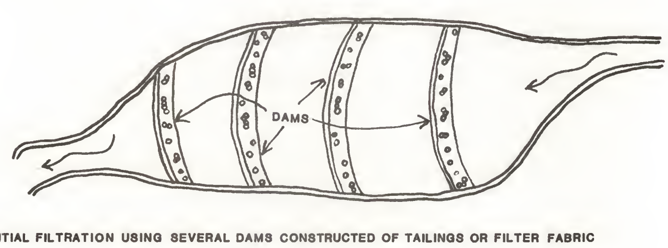
*DOWNSTREAM SLOPE DEPENDS ON GRADATION OF TAILINGS AND AMOUNT OF SEEPAGE



TAILINGS DAM USED TO IMPOUND WATER



X-SECTION OF AN IDEAL FILTER DAM



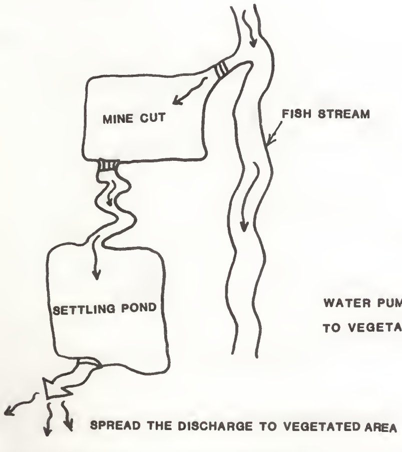
SEQUENTIAL FILTRATION USING SEVERAL DAMS CONSTRUCTED OF TAILINGS OR FILTER FABRIC

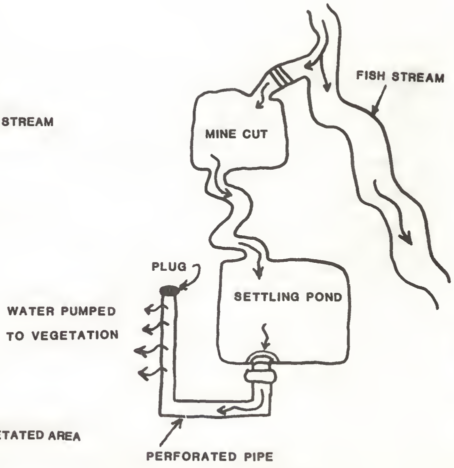
C. Land Application and Vegetative Filters

It is possible to use natural vegetation as a filter media. This should be considered if the wastewater sediment load is a very fine silt or clay which is not easily removed using just a settling pond. This control method can result in effective removal of the sediment load from mining wastewater when used in conjunction with a settling pond. The treated water either percolates into the soil or results in relatively sediment-free runoff to the receiving water. The resultant deposit of sediments on land can be beneficial in some cases and contribute to land reclamation.

This method is limited to mines having fairly large, flat or gently sloping vegetated areas downslope from the operation. Such an area could be used by diverting mine water to it. Thus, the use of diversion ditches or berms to direct water to an area where it can spread over the land is a possibility.

Note: Caution should be taken to avoid erosion.

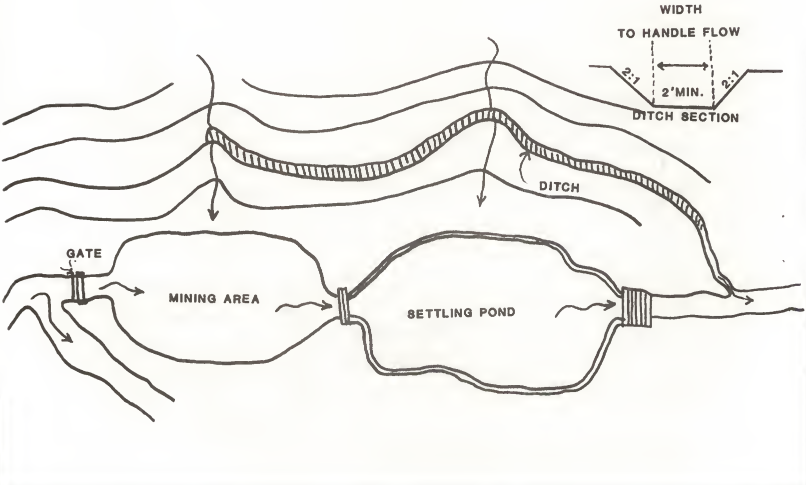




D. Diversion Ditches and Storm Surges

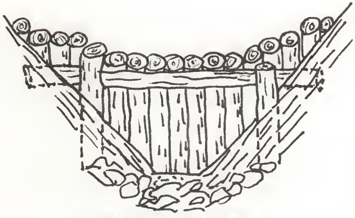
Diversion (channeling water before it reaches erodible materials) is usually accomplished by excavating ditches or channels upstream of the mine area. Flumes, culverts, riprap, and various forms of matting can be used in channels conveying water down steep slopes to prevent erosion. Dikes (berms) can be used in the same manner as ditches. Dikes and ditches are often used together when material excavated from a ditch is used to form a downslope dike. Also, where direct application of the mine water to the lands is possible, dikes can be used to contain and direct the flow. Dikes are usually made of the stripped material and should be solid enough to control the water and be stable. In most cases, diversion is an economical form of erosion control, although it is not meant to function as the sole erosion control measure.

Gradients of diverted streams must be kept low to minimize the velocity of the water flow.

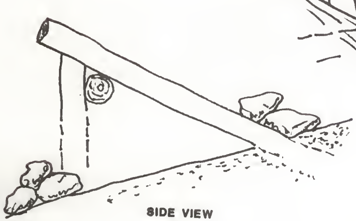


On steep gradients, diversion ditches frequently have to be constructed to fit the ground. In such cases checks built with native materials can effectively reduce the grade of the water course.

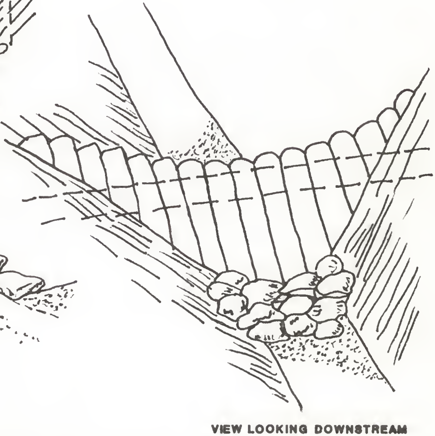
A log-and-pole structure is shown below. These structures, placed across waterways, are built from the timber that is generally available at the site. Log-and-pole structures retard the flow of runoff and catch the peak flow in the stream, thereby reducing the potential for stream erosion. The effectiveness of these structures can be increased further by building several structures at regular intervals along the drainageway to achieve a flatter ditch grade. A section in the middle of the structure must be lower than the sides to prevent erosion around the ends of the structure. Provision to clear settled material from behind the check should be made.



VIEW LOOKING UPSTREAM



SIDE VIEW



VIEW LOOKING DOWNSTREAM

V. CONCLUSIONS

1. Good planning can avoid regulatory problems and can increase mining efficiency.

2. Contact the land and water management agencies for required use authorizations and permits.

3. Ponds should be designed properly, with consideration given to minimum flow rate required, size of mine cut, and soil particle size. The detention method for sizing the pond is the most practical for most miners.

4. Jar tests can be made to check effluent quality.

5. Low overflow rates, a minimum of 10-hour detention times, and a pond design of the length twice the width are good rules of thumb and starting points to meet permit requirements.

6. Ponds must have regular maintenance. They should be cleaned or abandoned when less than two feet of freeboard exists.

7. Inlet and outlet structures must be build of durable materials to avoid erosion.

8. Storm surges must be considered in pond design.

9. Energy dissipaters reduce inlet water velocity, help prevent short-circuits, and increase settling efficiency.

10. Baffles increase effective length to width ratios.

11. Avoid treatment of storm water by bypassing it around your pond.

12. If possible, design a system which does not discharge to state surface waters; by recycling all wash-water or utilizing a treatment pond which seeps into the groundwater.